SOIL ORGANIC MATTER AND ROOT TURNOVER: THE ENRICHED BACKGROUND ISOTOPE STUDY

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RESEARCH OBJECTIVES

In the summer of 1999 there was a large atmospheric release of $^{14}CO_2$ near the Oak Ridge Reservation (ORR), Tennessee, presumably from a local incinerator. The rapid photosynthetic uptake of the $^{14}CO_2$ created a pulse label for studying carbon (C) cycling through the ORR forests. As part of a team from four DOE labs and UC Irvine, we are utilizing this whole-ecosystem isotopic label to study, and improve modeling of, processes in terrestrial carbon cycling. At Berkeley Lab, we are investigating (1) soil organic matter (SOM) dynamics, (2) the longevity of fine roots, and (3) leaf versus root inputs to SOM.

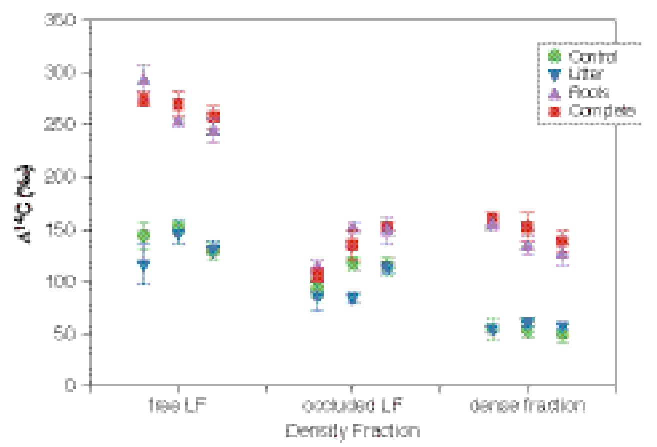

Figure 1. The radiocarbon content of SOM fractions from 0–15 cm depth at the Ultisol EBIS sites. The treatments are named for the source of elevated ^{14}C to the soil: roots, leaf litter, enriched leaves and roots (complete) or no enriched plant inputs (control). The three repeated symbols for each treatment and fraction are for the three years of sampling, 2001–2003.

APPROACH

The ORR team used a reciprocal transplant of enriched and near-background leaf litter to create four treatments, depending on type of plant ^{14}C inputs to soil: roots, leaf litter, both, or neither (no enrichment). We used a simple density fractionation method to separate SOM into interaggregate particulate organic matter (free light fraction), particulate organic matter occluded within aggregates (occluded light fraction), and organic matter complexed with minerals to form a dense fraction. We determined fine-root longevity by tracking the radiocarbon label in live and dead root populations. For fungal dynamics, ectomycorrhizae were hand-picked from freshly harvested roots. For microbial biomass, chloroform fumigation-extracts of soils were freeze-dried and combusted for graphitization. Radiocarbon content was measured at Lawrence Livermore National Laboratory by accelerator mass spectrometry. As a guide to interpreting the results, the more ^{14}C-depleted a sample, the slower its rate of input or turnover in the ecosystem.

ACCOMPLISHMENTS AND SIGNIFICANCE

The $\Delta^{14}C$ values of the SOM fractions reveal two important aspects of carbon cycling in these forest soils. First, considering only the control treatment, the mineral-associated (dense fraction) carbon is the most depleted in ^{14}C, showing that this fraction has the slowest turnover time, while the free light fraction is the fastest cycling. The depleted signature (and thus slow turnover time) of the occluded light fraction was unexpected, because it is chemically similar to the free light fraction. These results mean that the dominant mechanisms of carbon stabilization were interaction with minerals and physical protection by occlusion, rather than intrinsic recalcitrance of the organic matter.

Second, only the soils receiving elevated ^{14}C from roots (roots and complete treatments) become enriched, and in fact there is no significant difference between control and litter soils, showing that only root inputs are contributing to SOM. The importance of root inputs relative to leaf litter was also seen in the results for ectomycorrhizal fungi and total microbial biomass. These results directly contradict the predominant assumption that litterfall is the main source of soil carbon, and its corollary that carbon inputs to soil can be approximated by litterfall rates.

The Enriched Background Isotope Study (EBIS) data are used to improve models of soil C cycling . For example, in the root study, new roots grew from a mixture of recent photosynthate and 10–20% stored reserves from the previous year. These findings are helping us parameterize a root model and estimate fine-root turnover based on trends in atmospheric $^{14}CO_2$.

RELATED PUBLICATIONS

Joslin, J.D., J.B. Gaudinski, M.S. Torn, W.J. Riley, and P.J. Hanson-, Unearthing live fine-root turnover times in a hardwood forest: The roles of root diameter, soil depth, and root branching order. Biogeochemistry (in review), 2005.

Swanston, C.W., M.S. Torn, P.J. Hanson, J.R. Southon, C.T. Garten, E.M. Hanlon, and L. Ganio, Characterizing processes of soil carbon stabilization using forest stand-level radiocarbon enrichment. Geoderma (in press), 2005. Berkeley Lab Report LBNL-57409.

ACKNOWLEDGMENTS

This work was supported by the Office of Science, Office of Biological and Environmental Research, U.S. Department of Energy under Contract No. DE-AC03-76SF00098. EBIS is led by Paul Hanson, Oak Ridge National Laboratory.